MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2022/2023 (TERM ID 2210)

EOP3026 OPTOELECTRONICS DEVICES

(NE)

7 FEBRUARY 2023
9:00 A.M - 11:00 A.M.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 5 pages including cover page with FOUR questions.
2. Attempt **ALL** questions and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

LIST OF CONSTANTS:-

Electronic charge, $e = 1.602 \times 10^{-19}$ C
Planck's constant, $h = 6.626 \times 10^{-34}$ Js
Speed of light, $c = 3 \times 10^{8}$ ms^{-1}
Temperature [K], $T = (T\,[°C] + 273)$ K
Boltzmann constant, $k_B = 1.381 \times 10^{-23}$ JK^{-1}
Electron mass, $m_0 = 9.11 \times 10^{-31}$ kg

Question 1

(a) A simple silicone light emitting diode (LED) can be made from a p^+n-homojunction where the p^+-layer is relatively heavily doped as compared to the moderately doped n-layer and the same material is used for the p^+ and n layers.

(i) Describe the light emission mechanism of the LED.

[7 marks]

(ii) By using two schematic diagrams, sketch the energy band diagrams of the LED when it is operating at the zero bias and forward bias conditions. Label clearly the p^+-layer, n-layer, depletion region, conduction band, valence band and Fermi level on both diagrams.

[3+3=6 marks]

(b) A InGaAs/InP quantum-well LED is epitaxial growth by sandwiching an InGaAs layer between two InP layers. The badngap energy E_g of the InGaAs is 0.81 eV, conduction band offset ΔE_c is 0.22 eV, valence band offset ΔE_v is 0.38 eV, effective electron mass is $0.041m_0$, effective hole mass is $0.45m_0$ and the width of the quantum-well layer is 15 nm.

(i) Calculate the first conduction subband energy relative to the conduction band minimum.

[3 marks]

(ii) Calculate the first valence subband energy relative to the valance band maximum.

[3 marks]

(iii) Calculate the emitted photon energy due to the transition from first conduction subband to the first valance subbbad.

[3 marks]

(iv) Calculate the emitted wavelength.

[3 marks]

Continued.....

Question 2

(a) A poorly designed Fabry Perot heterostructure laser diode might has a large threshold current prior to achieving the lasing condition. Discuss **THREE (3)** ways for reduction of the threshold current of a laser diode.

[3×4=12 marks]

(b) A green colour laser diode emits a peak wavelength at 550 nm has a threshold current value of is 5 mA. When it is forward biased at 3.5 V, a forward current of 50 mA is injected into the active region and a 10 mW output optical power is emitted.

(i) Calculate the slope efficiency.

[3 marks]

(ii) Calculate the power conversion efficiency.

[3 marks]

(iii) Calculate the external quantum efficiency.

[3 marks]

(iv) Calculate the external differential quantum efficiency.

[3 marks]

(v) Why the external differential quantum efficiency is higher than the external quantum efficiency.

[1 mark]

Continued.....

Question 3

(a) Figure Q3(a) shows a photocurrent-reverse bias curve of an InGaAs/InP separate absorption avalanche photodiode (SAM APD).

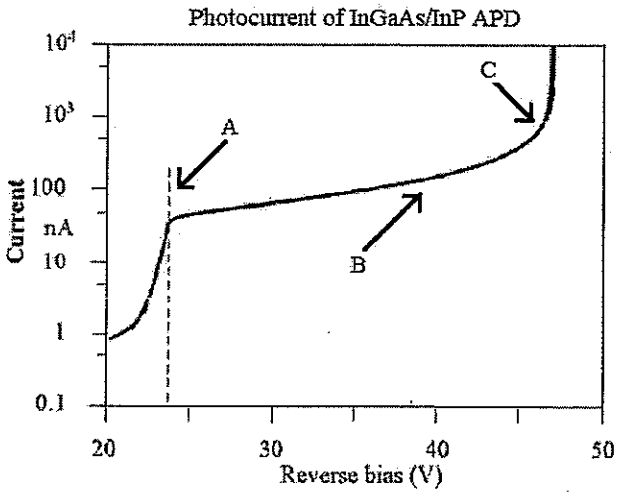

Figure Q3(a)

There are a few conditions, namely breakdown, avalanche and reach-through, can occur in the SAM APD while it is operating at different reverse bias values.

(i) State the names of the conditions that are labelled as A, B and C in the photocurrent-reverse curve (Figure Q3(a)).

[3 marks]

(ii) Discuss the conditions that are corresponding to the labels A, B and C.

[3×3=9 marks]

(b) A GaAsSb/GaAs SAM APD has a responsivity of 0.38 A/W at 1064 nm at unity gain. The APD is illuminated with an incident optical power of 2 μW.

(i) Calculate the quantum efficiency at unity gain.

[3 marks]

(ii) Calculate the primary photocurrent.

[3 marks]

(iii) Calculate the multiplied photocurrent when the multiplication factor is 50.

[3 marks]

(iv) Calculate the quantum efficiency and responsivity after the multiplication.

[2+2=4 marks]

Continued.....

Question 4

(a) Figure 4(a) and 4(b) show the opaque and finger contact designs for a solar cell.

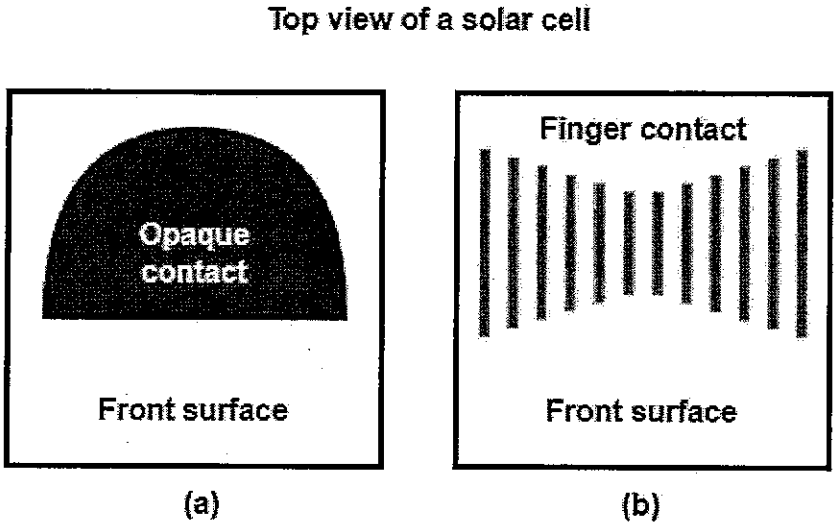

Figure 4: (a) Opaque contact and (b) Finger contact designs for a solar cell.

(i) Discuss how the designs of the contacts as shown in the Figure 4(a) and 4(b) affect the efficiency of a solar cell.

[2×3=6 marks]

(ii) Besides the contact designs, suggest **TWO** different methods that can be used to enhance the light collection of the solar cell.

[2×3=6 marks]

(b) A light with an intensity value of 100 $mWcm^{-2}$ is illuminated on a 100 cm^2 silicon solar panel with an efficiency value of 20% and an open circuit voltage of 12 V. The power generated from the solar cell is used to drive a DC electric motor with a resistance value of 50 Ω.

(i) Calculate the maximum optical power received by the solar cell.

[3 marks]

(ii) Calculate the current flows through the DC motor.

[4 marks]

(iii) Calculate the voltage drops across the DC motor.

[3 marks]

(iv) Calculate the short circuit current if the form factor is 0.7.

[3 marks]

End of Paper